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# Modeling of bioenergy impact on food security of EU countries

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**Abstract.** Ensuring the energy and food independence of each state will not only remain important but that its importance will continue to grow given the constant need for the state to properly guarantee the basic needs of the population. However, the rapid development of bioenergy is a potential precondition for the fuel and food conflict over agricultural raw materials. The article examines the relationship between food safety indices and the overall share of energy from renewable sources and bioenergy production in 13 European countries. The main factors characterizing the food security of these countries for the period from 2012 to 2018 are identified. Statistical methods of correlation analysis are used to determine the links between the outlined factors. It is studied that in most countries the prosperity of the bioenergy sector of agricultural enterprises does not affect the main indices of food security. In 5 countries (Poland, Germany, Norway, Spain, the Czech Republic) correlations were found, but for the most part, they are direct. It means that large values of one variable are associated with large values of the other, in other words with increasing the share of bioenergy production and overall share of energy from renewable sources, food safety indices also increase.

## 1. Introduction

Today, ensuring energy independence is one of the key challenges facing Ukraine, and ignoring this issue is a global destabilizing factor, which in turn leads to a decline in economic and, consequently, national security. One of the possible ways for solution of this problem is the large-scale introduction and use of renewable energy sources. Energy diversification is an objective reality that will determine the development of key sectors of the economy and form the basis of the country's energy independence..

Production and use of bioenergy are growing at a very rapid pace in countries, where the government, business, scientists, and investors are involved in this sector. The main task of modern research in the field of bioenergy is to find the most effective solutions in terms of sustainable development and should be aimed at food and energy security, economic, and social development.

## 2. Critical literature review

Traditionally, agriculture is the main source of the food supply. At the same time, this sector is one of the three sources of biomass production, which makes it possible to obtain goods with higher added value. This leads to increased competition for raw materials and food security risks.



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Therefore, some researchers think that the rapid development of bioenergy could be a reason for the global food crisis [1]. As lands suitable for sowing are limited, the growth of biofuel production (which has tripled in recent years) from cereals and oilseeds leads to a reduction in the food supply. It is widely believed that the significant political and economic incentives received by the bioenergy sector have negative consequences for the sustainable development of agriculture [2, 3]. Concerns are also emerging at the international level: the report of the Food and Agriculture Organization of the United Nations "The state of affairs in the field of food and agriculture" indicates the need for in-depth research on the role of biofuels in food and energy security [4].

Authors [5] report that the large-scale use of bioenergy, may raise food prices and increase the amount of people threatened by hunger in many areas of the world. Whereas researchers [6] state that the use of crop residues for bioenergy can play a crucial role in climate change mitigation without jeopardizing food security. These issues are studied by spatiotemporally explicit approach combined with stakeholder interviews in the base of the case study of North Rhine-Westphalia in Germany.

Today, there are many different approaches to studying the impact of all factors individually or collectively on the development of the national economy and strengthening energy and food security. Ukrainian researchers Yu. Kyrylov and M. Huba have determined several threats to the further "aggressive" development of the bioenergy direction of agricultural enterprises:

- undoubtedly, the competition of food and energy crops will become fiercer, the problem of ensuring national food security will become more acute and especially important;
- we can expect increased depletion of agricultural land;
- the scale of conservation of degraded unproductive lands, as well as their transformation into afforestation and renaturalization into natural biogeocenoses will be limited [7].

Thus, it is believed that the growing demand for raw materials for biofuels encourages farmers to reduce the land under food crops and redistribute them in favor of energy, as their production is more profitable [8].

J.C. Bureau and J. Swinnen [9] examines the evidence of the impact of EU policy on global food security, focusing on several EU policy areas: agricultural policy, bioenergy policy, food standards, trade policy and development policy (food aid).

L. Nagyová [10] determined that one of the decisive factors influencing the economic stability of agriculture, in particular in the field of food products, is the efficiency of production. Yu. Bingxin and Y. Lingzhi [11] found that in order to address their unique food and bioenergy problems in vulnerable developing countries, they need different methods of political support in this matter.

Yu. Maksymiv [12] slightly changed the approach to the use of food and non-energy security. The researchers analyzed the domestic market of solid biofuels by product groups (fuel briquettes and wood pellets) and consumers (households and businesses) and thus proved that to strengthen Ukraine's energy security to develop domestic production of solid biofuels, which should be aimed at ensuring the domestic market, not exports. It also outlines public policy measures that can stimulate the existing potential of woodworking and agricultural enterprises for the production of solid biofuels and the demand for these products among consumers.

The view that expanding the use of bioenergy will lead to serious competition with food is not accepted by many experts [13]. According to the Food and Agriculture Organization of the United Nations [14], more than 80% of the world's future demand for food and feed will be met by increasing productivity. Thus, in particular, between 1961 and 2009, the global arable land area increased by about 12%, and agricultural production by 150%, due to increased productivity. Therefore, the situation with global food security is constantly improving, as indicated by the steady increase in average food consumption per capita [14].

The sustainability of bioenergy has been discussed a lot in recent years. Sustainability criteria have been introduced, mainly focusing on the effects of bioenergy products on food security. Therefore, a number of European countries' strategies include the principle of "nutrition first", indicating that increasing the production of agricultural biomass should first focus on meeting food needs before supplying raw materials for energy purposes.

However, insufficient attention has been paid to studying the impact of increasing the share of renewables and bioenergy production on food security. An important task is to study the experience of European countries in this matter. It will help to develop a strategy for boosting Ukraine's energy independence without threatening its food security.

The aim of the research is to study the correlation between the share of energy from renewable sources and food security indices, the share of bioenergy in total primary production and food security indices using statistical methods.

### 3. Materials and Methods

The initial data for the study were official statistics, energy balances, scientific literature on determining the foundations of food security and the development of the national economy. Indicators of bioenergy production and the share of energy from renewable sources were taken from the energy reports of the countries posted on the Eurostat website. The food security indices consider the key challenges of affordability, availability, and quality across a number of countries. The methodology for food security indices was developed by The Economist Intelligence Unit and with advice from a number of experts.

The main statistical methods used in the study were the Kolmogorov-Smirnov consistency criterion (to determine whether empirical distributions are subject to the same law or model) and the Spearman rank correlation coefficient (to find correlations between food safety indices and the share of bioenergy and overall share of energy from renewable sources).

### 4. Results and Discussion

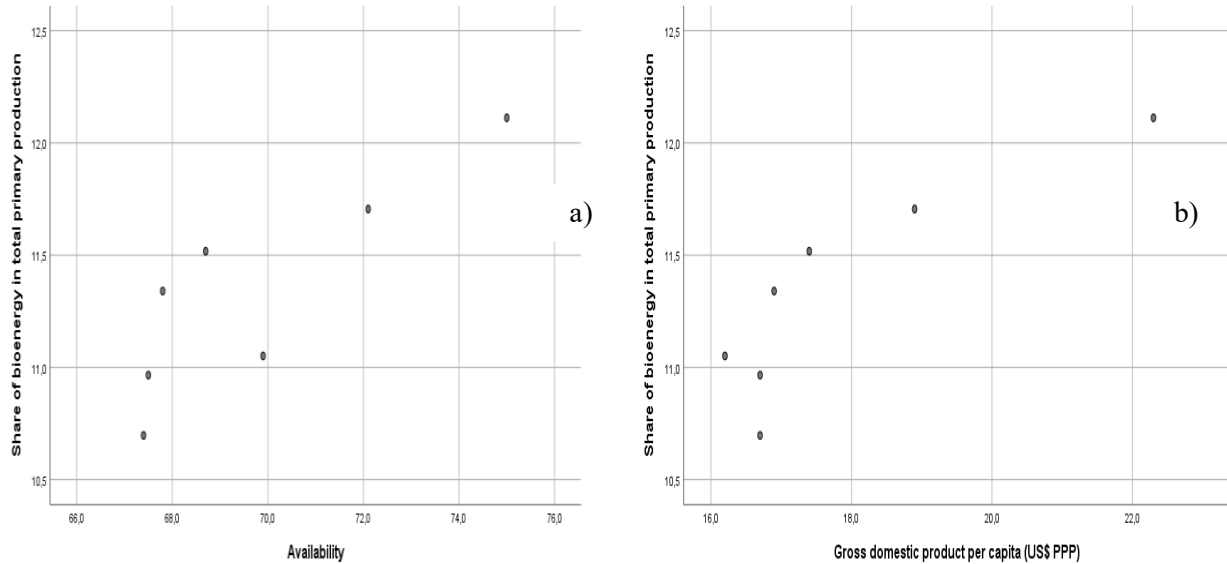
In response to the concerns of the world community, the Food and Agriculture Organization of the United Nations was established in 2007 and, as a result, a bioenergy and food security project was prepared [15]. The aim of the project was to ensure that the problem of food security in the bioenergy sector is taken into account and to develop a system of criteria and indicators. Exploration in this area has contributed to a further understanding that, despite a number of benefits, bioenergy can pose certain threats to food security: social, economic, and environmental.

The Economist's research department has developed global food safety indices [16]. Food security is defined as the conditions in which people in all circumstances have physical, social, and economic access to adequate and nutritious food that meets their nutritional needs for a healthy and active life [17]. Based on this definition, food safety indices are calculated in terms of affordability, availability, safety, and quality of food in 113 countries. The overall index is a dynamic quantitative and qualitative benchmarking model, which consists of 34 unique indicators. This set of indices present different aspects of food security across both developing and developed countries [16].

Our study aims to analyze the food security indices of 13 European countries (including Ukraine) from 2012 to 2018 and find their correlation with the share of bioenergy in total primary production and overall share of energy from renewable sources. The food security indices taken into account included: overall index of food security, affordability, availability, quality and safety, change in average food costs, the proportion of the population under global poverty line, gross domestic product per capita, agricultural import tariffs, presence and quality of food safety net programs, access to financing for farmers, the sufficiency of supply, funds for agricultural research and development, level of infrastructure development in this field, stability risk in politics, corruption, food loss, quality of food, its safety, etc. The end result is to find out which countries are most and least sensitive to food security as bioenergy production increases.

As a result of the study of indicators for Poland, it was found that there is a direct and close correlation between the index "Food Availability" and "Share of bioenergy in total primary production" ( $r_s = 0.893$ ,  $p = 0.007$ ) (Fig. 1, a). Significant progress in the agricultural sector of Poland is accompanied by the development of bioenergy. As we can see, the agricultural sector does not suffer from the development of bioenergy. There is also a direct correlation between the index "Gross domestic

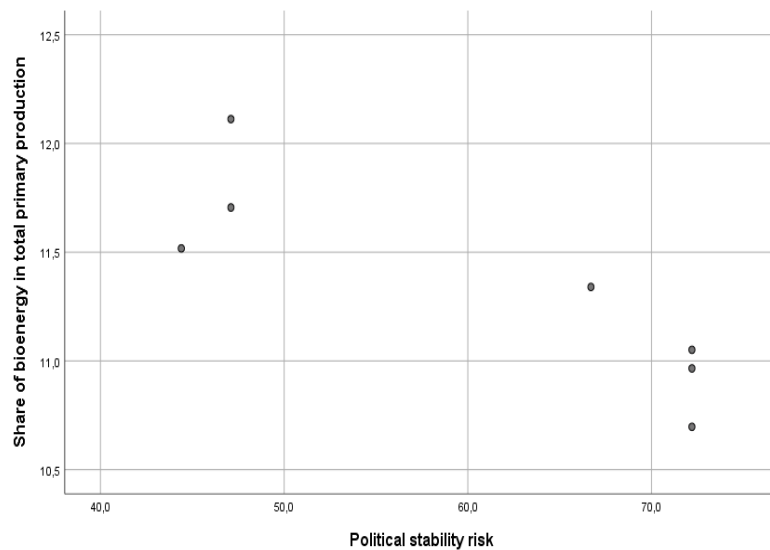
product per capita" and "Share of bioenergy in total primary production" ( $r_s = 0.883$ ,  $p = 0.008$ ) (Fig. 1, b).



**Figure 1.** Correlation between the indicators “Share of bioenergy in total primary production” and “Food availability” (a) and “Gross domestic product per capita” (b), Poland

Source: built by the author

However, among the studied correlations there is only one statistically significant inverse relationship: between the risk of political stability in Poland and the share of bioenergy production ( $r_s = -0.842$ ,  $p = 0.017$ ). It is no secret that the development of bioenergy often depends on the political will of the heads of state and a stable political course of the country, as such development is based on a favorable legal framework and public investment (Fig. 2).



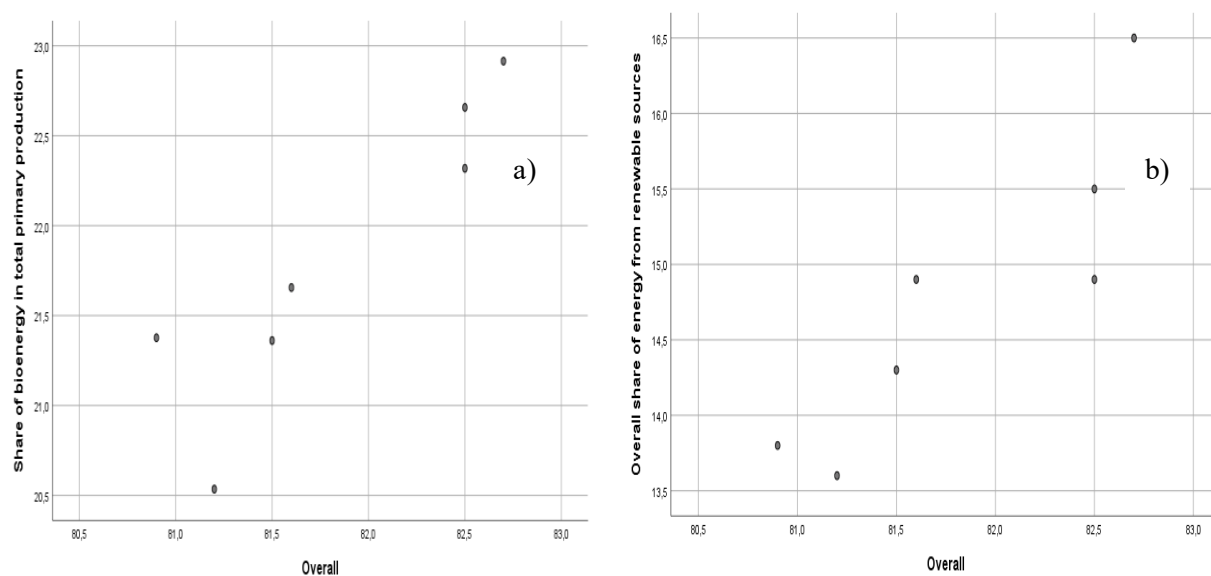
**Figure 2.** Correlation between the indicators “Share of bioenergy in total primary production” and “Political stability risk”, Poland

Source: built by the author

The correlation between the general indicator of food security and biofuel production is direct ( $r_s = 0.857$ ,  $p = 0.014$ ). The results show that between bioenergy production and renewable energy sources in Poland and the main food safety indices are either not correlated at all, or they have a direct relationship, i.e. with increasing bioenergy production, the food safety index increases.

Analyzing the indicators in Germany, it was found that there is a direct correlation between the overall food safety index and the share of bioenergy production ( $r_s = 0.883$ ,  $p = 0.008$ ) (Fig. 3, a), and with the overall share of energy from renewable sources ( $r_s = 0.936$ ,  $p = 0.002$ ) (Fig. 3, b). That is, the production of biofuels does not affect the overall food safety index, which could be stated in the inverse correlation.

It is noteworthy that the relationship between the index "Average food costs" and bioenergy production is inverse and statistically significant ( $r_s = -0.883$ ,  $p = 0.008$ ). Thus, in Germany, bioenergy affects the average cost of food with increasing costs. Similarly, as in Poland, there is a direct correlation between the index "Gross domestic product per capita" and "Share of bioenergy production" ( $r_s = 0.991$ ,  $p = 0.00001$ ).

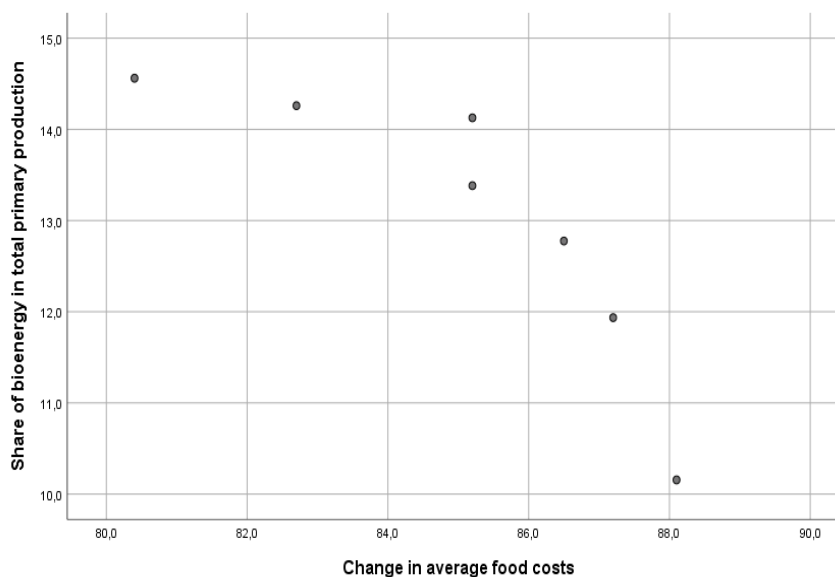


**Figure 3.** Correlation between the indicators "Overall food security" and "Share of bioenergy in total primary production" (a) and "Overall share of energy from renewable sources" (b), Germany  
Source: built by the author

Among the factors studied in Norway, only one statistically significant correlation was found: between food quality and biofuel production. The relationship is inverse:  $r_s = -0.927$ ,  $p = 0.0026$ . This may indicate that the rapid development of bioenergy has a negative impact on food. However, additional research over a longer period of time is needed to confirm or refute the result.

In Spain, correlations are found only between the index "Food loss" and the share of bioenergy in total primary production ( $r_s = 0.945$ ,  $p = 0.0013$ ). Unlike other countries in Spain, there is an inverse relationship between the corruption index and indicators of bioenergy development ( $r_s = 0.866$ ,  $p = 0.012$ ). It is likely that the corruption component hinders the implementation of bioenergy projects.

In the Czech Republic, a direct correlation was determined for the Agricultural Infrastructure Index and the share of bioenergy in total primary production ( $r_s = 0.791$ ,  $p = 0.034$ ). Accordingly, we can conclude that the development of the bioenergy sector is associated with the logistics of agricultural enterprises. The inverse relationship between the index "Change in average food costs" and the share of bioenergy in total primary production ( $r_s = -0.991$ ,  $p = 0.00001$ ) is one of the elements confirming the absence of a threat to food security of the state (Fig. 4).



**Figure 4.** Correlation between the indicators "Change in average food costs" and "Share of bioenergy in total primary production", the Czech Republic

Source: built by the author

Analyzing the indicators of bioenergy and food security for Italy, France, Slovakia, Sweden, Romania, Belgium, Finland, and Ukraine, no statistically significant correlations (at  $p \leq 0.05$ ) were found, indicating a lack of relationship between the studied factors in these countries.

## 5. Conclusions

According to the results of statistical studies, no correlations were found between food security indices and the share of bioenergy and renewable energy sources in 8 out of 13 countries (for the period of 2012-2018).

According to the indicators of the countries we study, the agricultural sector does not suffer losses with the development of renewable energy, in particular bioenergy. Biofuel production contributes to the development of the local economy, rural areas and the improvement of infrastructure. In some countries, GDP growth is directly correlated with bioenergy production, which is noticeable, in particular, in the example of Poland. Also, it was found that biofuel production does not affect the overall food safety index, and these indicators have a direct correlation, i.e. show common growth trends.

The statistically significant inverse correlation between the risk of political stability and the share of bioenergy production indicates the dependence of the sector on the political will of the country's leadership and a stable political course, as such development is based on a favorable legal framework and public investment in the industry. Thus, a necessary precondition for the development of the bioenergy sector is a prudent public policy that takes into account all aspects, including food security. At the same time, in Germany, bioenergy production affects the average cost of food with increasing costs. Therefore, the development of bioenergy in the state can also be determined by the environmental consciousness of its citizens.

Further research should focus on the study of correlations between indicators on the example of more countries in the world and over a much longer period of time using different statistical methods.

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